Western Bridge Engineers' Seminar

September 27, 2011

ADOT LRFD Bridge Substructure Policies with Emphasis on Interaction Between Structural and Geotechnical Specialists

Naresh C. Samtani, PhD, PE, D.GE
President, NCS Consultants, LLC
www.ncsconsultants.com

Amin Islam, PhD, PE
ADOT Bridge Technical Section Leader

Acknowledgements

***Only key members listed**

- **ADOT Materials Group**
  – Jim Wilson, PE; Norm Wetz, PE
- **ADOT Bridge Group**
  – Navaphan Viboolmate, PE, Mokarrom Hye, PE
- **NCS Consultants, LLC**
  – Ed Nowatzki, PhD, PE
- **Numerous reviewers**
  – External reviewer: Jerry DiMaggio, PE (FHWA/TRB)

ADOT LRFD Effort for Bridge Substructures

- Effort started in 2004
- Emphasis on interaction between bridge (structural) and geotechnical specialists
- Six policy memoranda to-date

- Joint effort by ADOT’s Bridge Group and Materials (Geotechnical) Group
  - Lots of meetings and discussions

Goal of Policy Memoranda

- Ensure consistent application of LRFD principles by the following:
  - ✓ Bridge (structural) and geotechnical specialists
  - ✓ ADOT personnel and consultants
  - ✓ ADOT policies and AASHTO specifications
  - ✓ ADOT and local agencies, e.g., Counties and Towns
  - ✓ Value Analysis (VA) and Value Engineering (VE)
  - ✓ Various project delivery methods
    - ➢ Design-bid-build, design-build, CM at Risk, etc.

Policy Memoranda

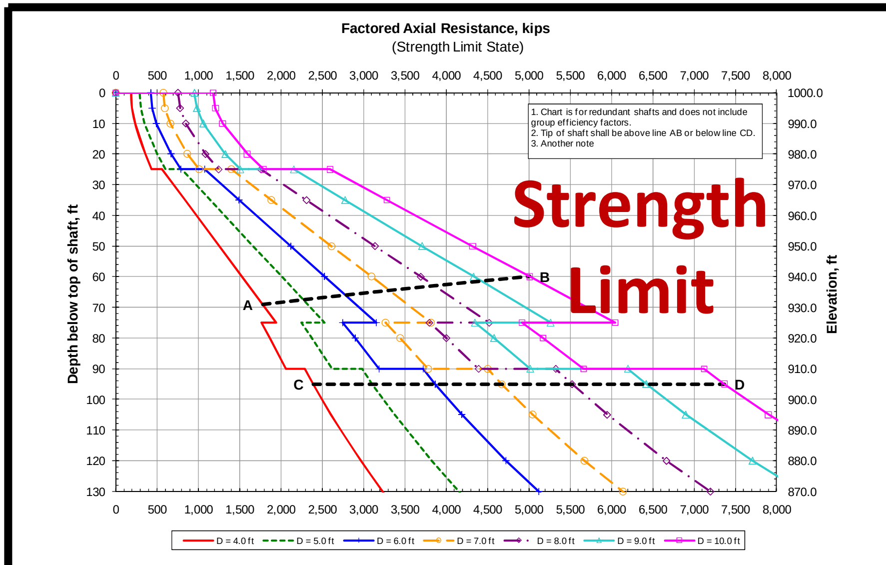
Memorandum		Topic	Guidance
1	ADOT DS-1	Drilled Shafts	Axial load analysis
2	ADOT DS-2		Definition of gravels and gravelly soils
3	ADOT DS-3		Lateral load analysis
4	ADOT SF-1	Spread Footings (Piers/ Walls)	Bearing resistance and settlement
5	ADOT SF-2		Limiting eccentricity
6	ADOT SF-3		Sliding and bearing resistance factors

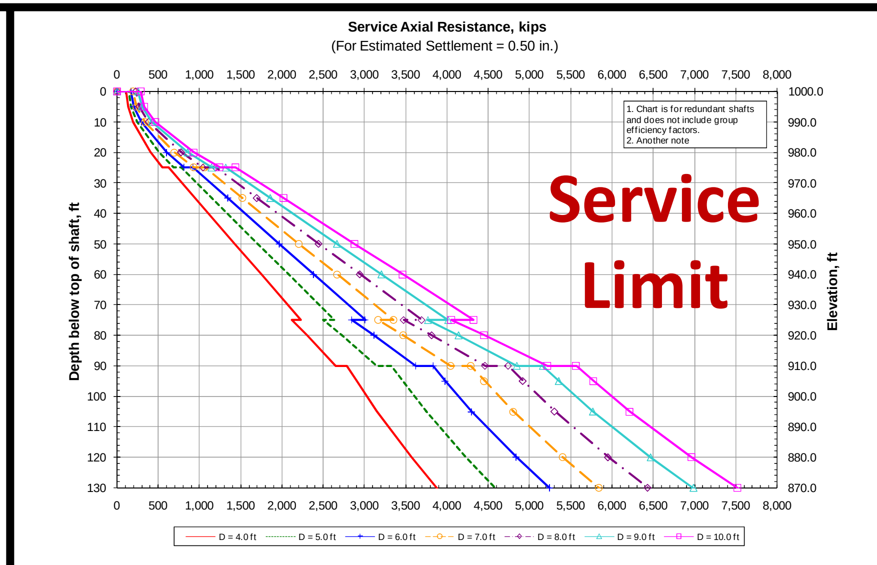
Approach to Each Policy Memorandum

- Clearly identify the topic of discussion
- Link to specific AASHTO sections and articles
- Note any deviations with background and justification
- Provide extensive discussion (commentary)
- Provide design guidelines including example problems
- Extensive internal and external reviews
- Review and update (if necessary) after release of every update of AASHTO LRFD bridge specifications
  - Maintain detailed revision log

1 ADOT DS-1 (Drilled Shafts) Axial Load Analysis

- Chart solution for strength and service limit states
  - Memo includes design guidelines including example problem

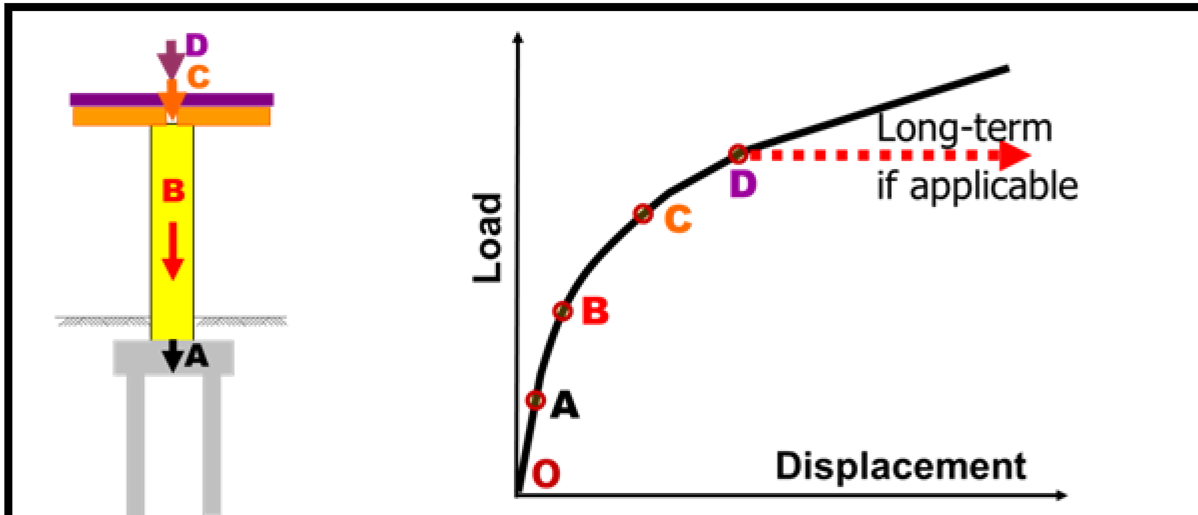




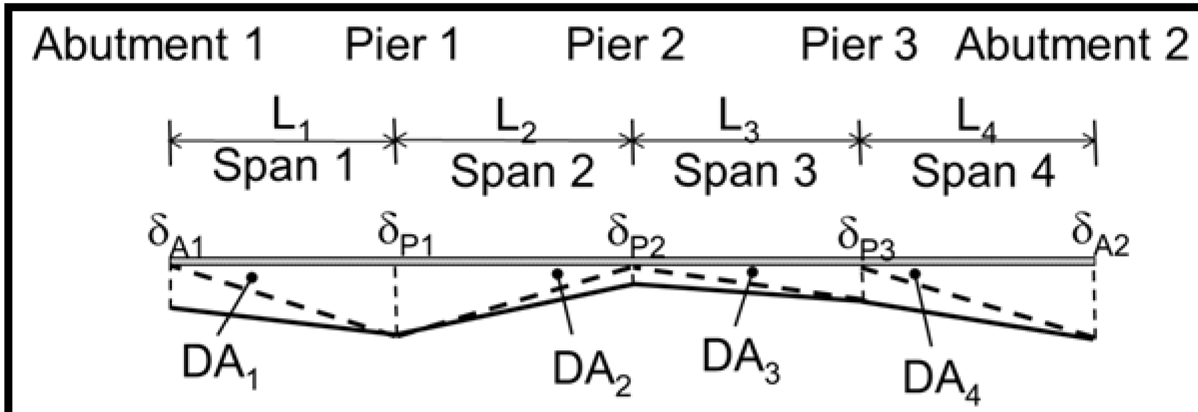
- Consideration of construction stages
- Interpretation of total and differential settlements

1 ADOT DS-1 (Drilled Shafts) Axial Load Analysis

Consideration of Construction Stages



Interpretation of Total and Differential Settlements

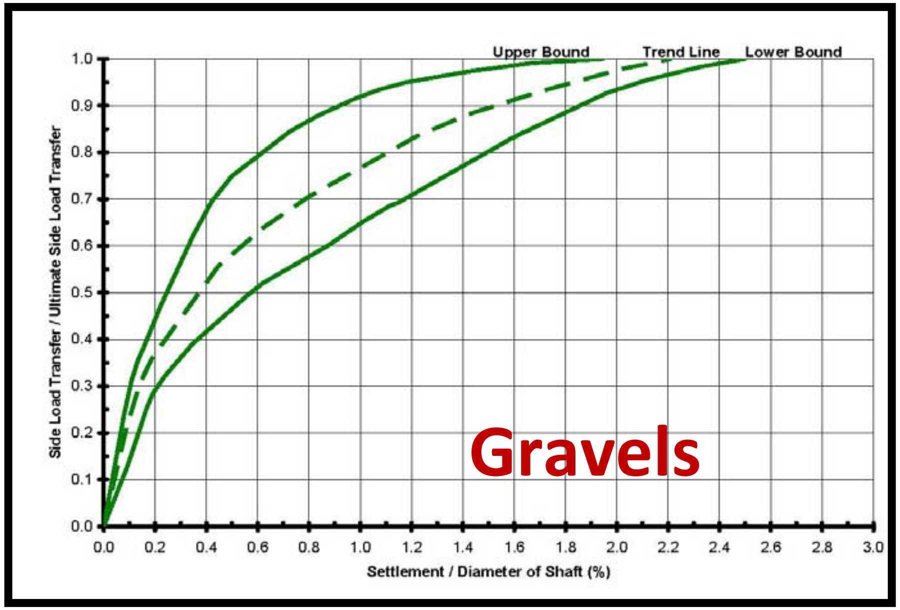


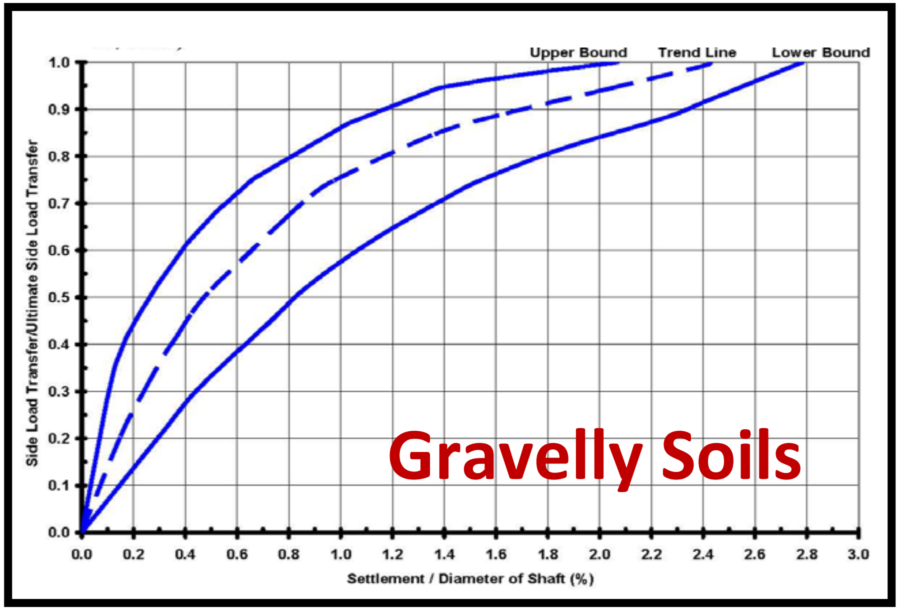
2 ADOT DS-2 (Drilled Shafts) Definition of Gravels and Gravelly Soils

- AASHTO makes a distinction between soil, rock, and intermediate geomaterial (IGM)
- For drilled shafts, AASHTO has different resistance formulations for different geomaterials
- Nominal resistance for gravelly soils is greater than non-gravelly soil
  - Temptation to use gravelly soil formulation arbitrarily to get more nominal resistance and reduce shaft size
- Base (tip) resistance for an IGM is found to be less than measured in Arizona soils (and in general for most places)

2 ADOT DS-2 (Drilled Shafts) Definition of Gravelly Soils

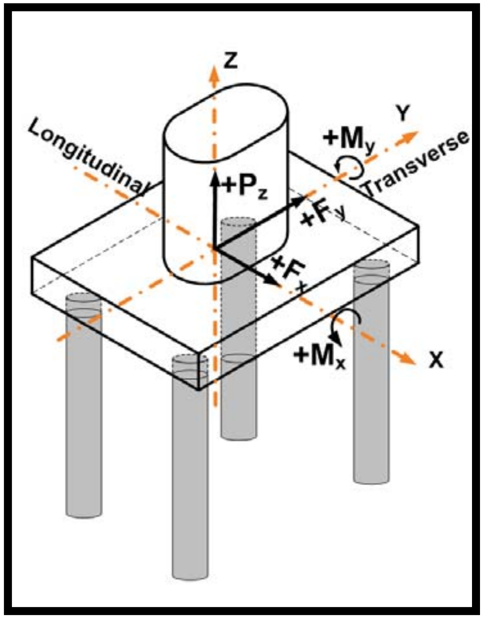
- Memo provides clear guidance for
  - Definition of gravels and gravelly soils
  - Side and tip resistance formulations
  - Resistance mobilization curves





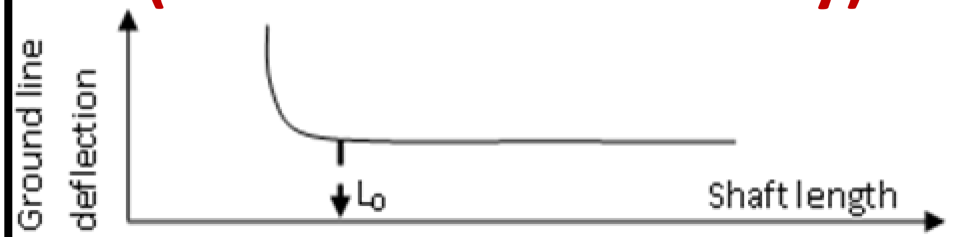
3 ADOT DS-3 (Drilled Shafts) Lateral Load Analysis

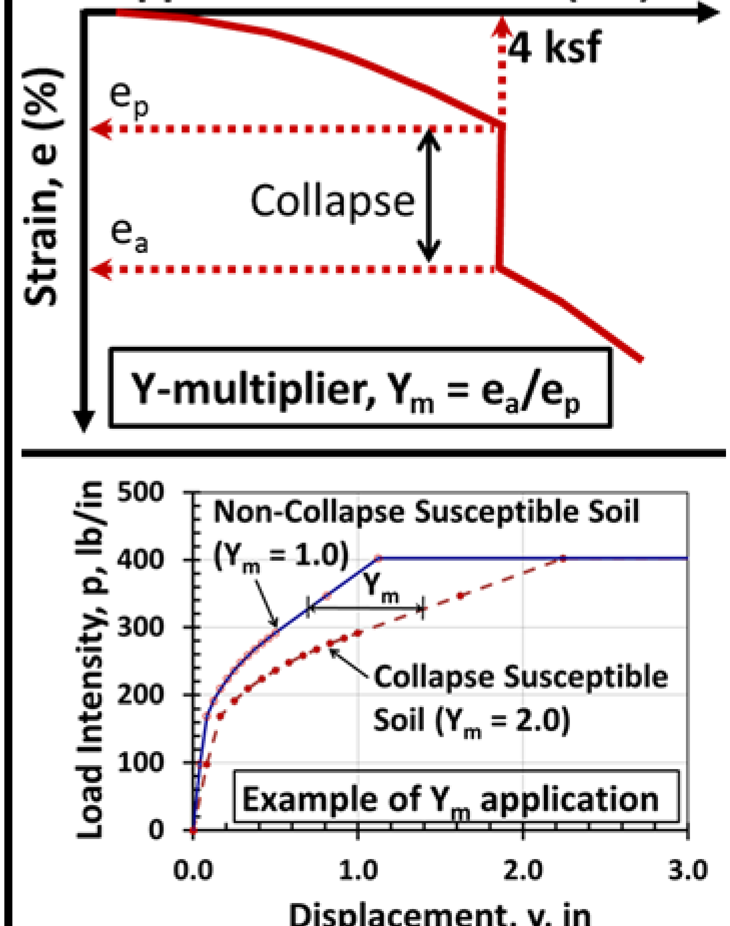
- Step by step procedure to evaluate the following:
  - Geotechnical stability (strength limit)
  - Structural stability (strength limit)
  - Structural serviceability (service limit)
- Guidance for proper selection of analytical methods for groups
- Depth to fixity model
- Model for collapsible soils

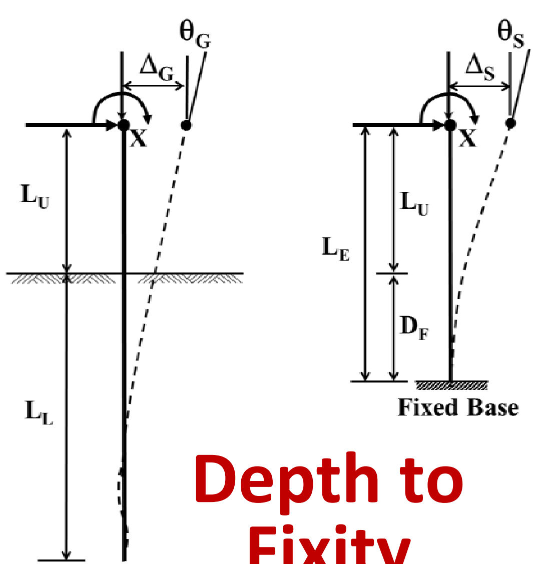


3 ADOT DS-3 (Drilled Shafts) Lateral Load Analysis

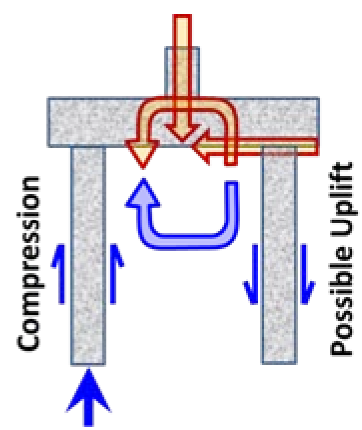
Overturning (Geotechnical Stability)







Depth to Fixity

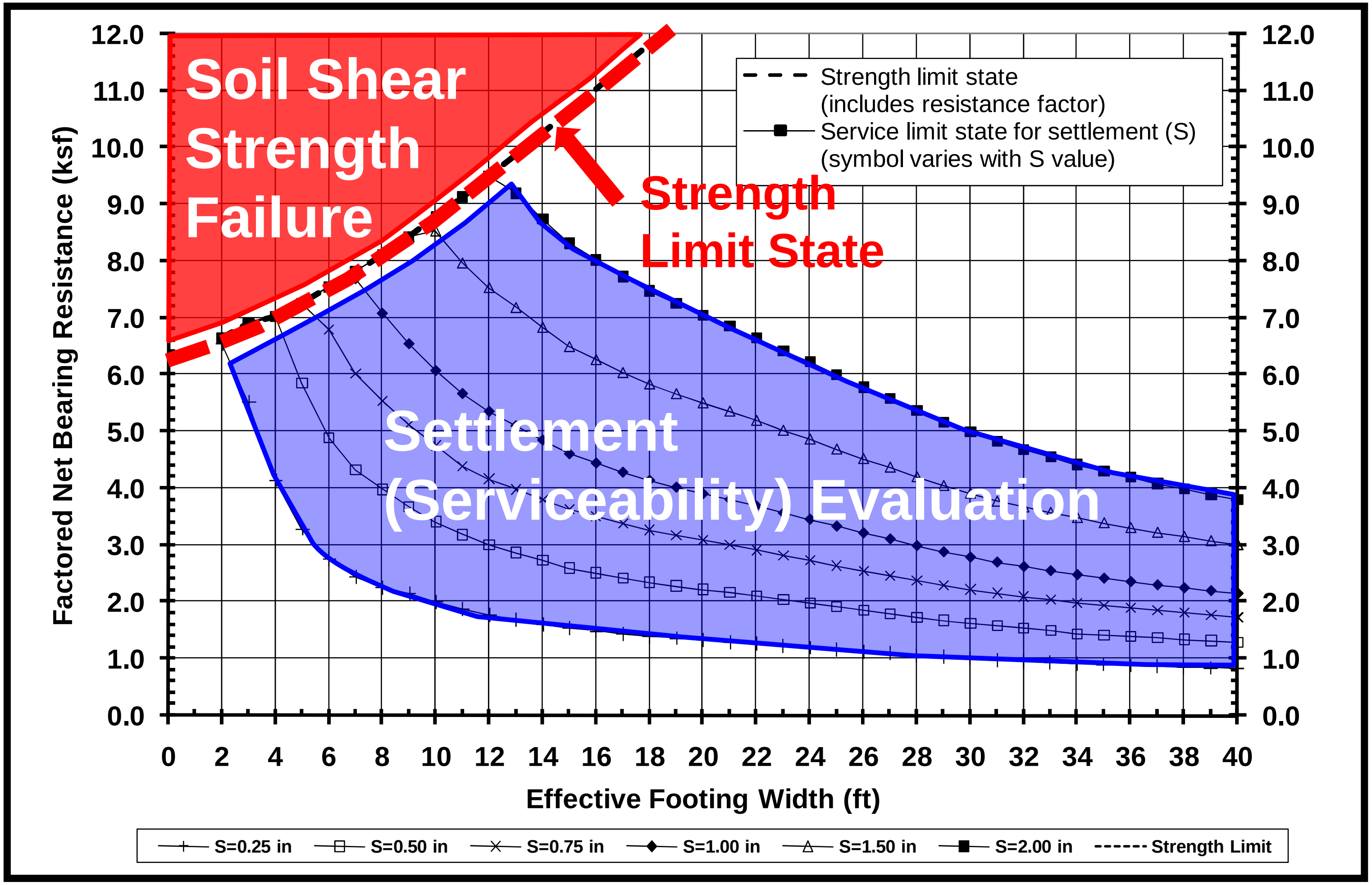


Group Behavior

4 ADOT SF-1 (Spread Footings – Piers/Walls) Bearing Resistance and Settlement

- Service limit state often controls plan size (L x B) of spread footings for transportation structures
- Strength limit state controls shear failure in soils as well as thickness of spread footings
- Memo integrates service and strength limit state designs through development and use of bearing resistance chart
  - Memo includes an example problem
- Reduces re-work between bridge and geotechnical specialists

4 ADOT SF-1 (Spread Footings – Piers/Walls) Bearing Resistance and Settlement

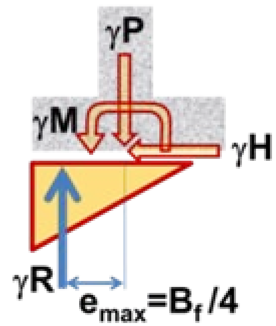


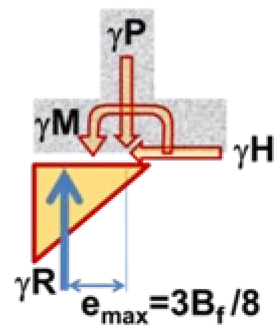
5 ADOT SF-2 (Spread Footings – Piers/Walls) Limiting Eccentricity

- **Concern: Existing ADOT standards for walls based on ASD were found to be inadequate while using AASHTO LRFD criteria for e_{max}**

Soils	Rocks

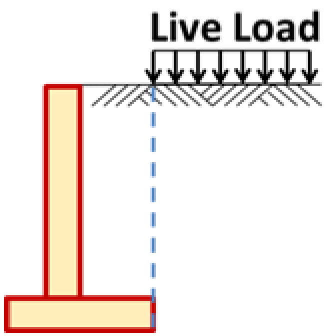
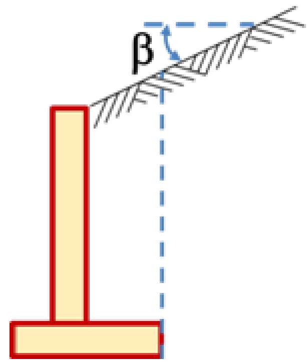
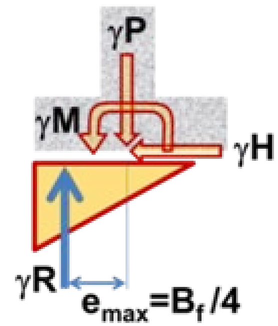
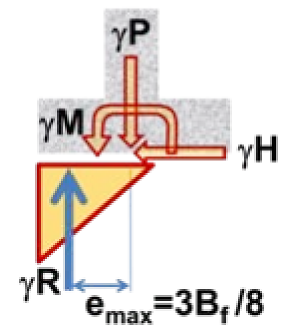
B_f is total footing width





- Current AASHTO criteria are based on load factors from Load Factor Design (LFD) in 17th Edition of AASHTO and not on LRFD method
- Performed extensive re-calibration using current load factors from Section 3 of 5th Edition of LRFD specs

5 ADOT SF-2 (Spread Footings – Piers/Walls) Limiting Eccentricity

Case A	Case B	Soils	Rocks
			

B_f is total footing width

Detailed Commentary in ADOT SF-2

	Soils	Rocks
ADOT SF-2	$e_{max} = B_f\left[\frac{1}{3} - \frac{\beta^o}{320}\right]$	$e_{max} = B_f\left[\frac{3}{7} - \frac{\beta^o}{500}\right]$
AASHTO (agenda item)	$e_{max} = B_f\left[\frac{1}{3}\right]$	$e_{max} = B_f[0.45]$

6 ADOT SF-3 (Spread Footings) Sliding and Bearing Resistance Factors

From AASHTO Table 10.5.5.2.2-1 in Section 10 (Foundations)

Method/Soil/Condition		Resistance Factor
Bearing Resistance	Theoretical method (Munfakh et al., 2001), in clay	$\phi_b = 0.50$
	Theoretical method (Munfakh et al., 2001), in sand, using CPT	$\phi_b = 0.50$
	Theoretical method (Munfakh et al., 2001), in sand, using SPT	$\phi_b = 0.45$
	Semi-empirical methods (Meyerhof, 1957) – all soils	$\phi_b = 0.45$
	Footings on rock	$\phi_b = 0.45$
	Plate load test	$\phi_b = 0.55$
Sliding	Precast concrete placed on sand	$\phi_\tau = 0.90$
	Cast-in-place concrete on sand	$\phi_\tau = 0.80$
	Cast-in-place or precast concrete on clay	$\phi_\tau = 0.85$
	Soil on soil	$\phi_\tau = 0.90$
	Passive earth pressure component of sliding resistance	$\phi_{ep} = 0.50$

6 ADOT SF-3 (Spread Footings) Sliding and Bearing Resistance Factors

From AASHTO Table 11.5.6-1 in Section 11 (Abutments, Piers & Walls)

Wall Type and Condition		Resistance Factor
Mechanically Stabilized Earth Walls, Gravity Walls, and Semi-Gravity Walls		
Bearing Resistance	• Gravity and semi-gravity walls	0.55
	• MSE walls	0.65
Sliding		1.0

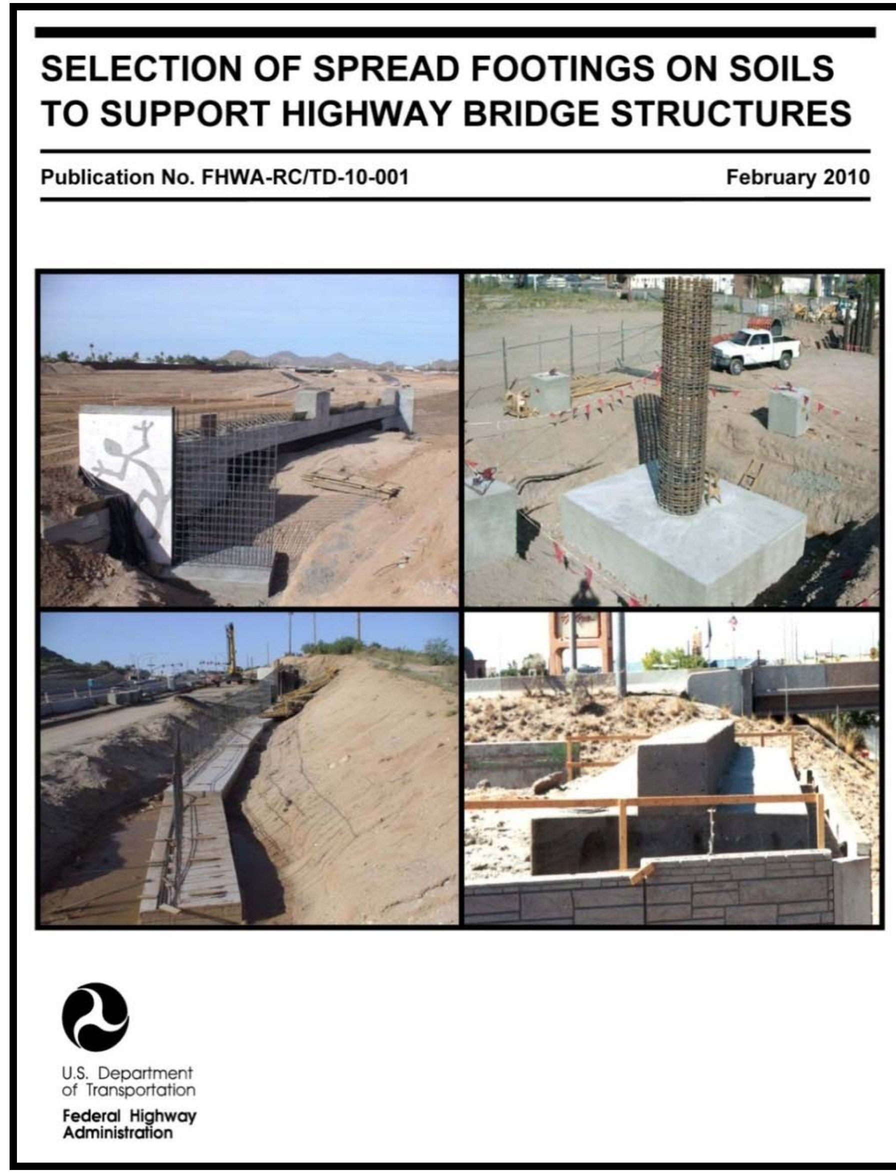
- Cannot account for:
  - Passive resistance for keyed foundations
  - Different combinations of soil and concrete types
  - Methods of analysis
- Section 11 values are based on specific EH/EV ratios
- Memo clarifies the correct choice and application of the factors

Effect of Policy Memoranda

- Consistent presentation and use of geotechnical recommendations
- Mitigate misinterpretation and misapplication based on comparison between LRFD and ASD approaches
- Mitigate "head in the sand" approach
- Foster active interaction between bridge and geotechnical specialists
- Application at national level and interest from other states

Example of Synergy with FHWA

- ADOT guidelines have resulted in national manuals
- Comprehensive flow chart and an example problem including some guidance for structural aspects



Is the Work Done?

- **Absolutely not !**
- Key Item: Coordination with hydraulic specialists for waterway crossings
  - Significant work done by Pima County
    - Contact Dave Zaleski (Pima County Bridge Engineer)
- **Continuing parallel work on MSE walls and approvals**
- Others
  - Need to update/revise some ADOT manuals and drawings
  - Topics such as buried structures (culverts), lateral squeeze, seismic design, etc.

Where to Access ADOT Policy Memoranda

- **ADOT website**

  http://www.azdot.gov/Highways/Materials/Geotech_Design/

- **NCS website**
  - www.ncsconsultants.com
  - Provides additional commentary and blog discussions on memoranda
  - Lot of other LRFD material for free download

Summary

- ADOT has a streamlined process for LRFD implementation
- Use policy memoranda for practical implementation of LRFD for bridge substructures
- Encourages and requires better communication between bridge and geotechnical specialists

If you would like to discuss LRFD visit and blog at www.ncsconsultants.com

Western Bridge Engineers' Seminar

September 27, 2011

ADOT LRFD Bridge Substructure Policies with Emphasis on Interaction Between Structural and Geotechnical Specialists

Naresh C. Samtani, PhD, PE, D.GE
President, NCS Consultants, LLC
www.ncsconsultants.com

Amin Islam, PhD, PE
ADOT Bridge Technical Section Leader